LANSCE
Los Alamos Neutron Science Center

Research Proposal for the use of Neutron Science Facilities

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Proposal Number: 20111511
Submission Number: S1522
Date Received: 03/02/11

Program Advisory Subcommittee: Basic Nuclear/Particle Physics
Focus Area:

Flight Path/Instrument: 1FP14 / DANCE
Estimated Beam Time (days): 14
Days Recommended: 0
Dates Desired:
Impossible Dates:

TITLE
Neutron Capture Experiment on 117,119Sn

☐ Continuation of Proposal #:
☐ Ph.D Thesis for:

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RESEARCH AREA		FUNDING AGENCY
☐ Biological and Life Science	☐ Mat'l Science (incl Cond Matter)	☐ DOE/BES
☐ Chemistry	☐ Medical Applications	☐ DOE/OBER
☐ National Security	☐ Nuclear Physics	☒ DOE/NNSA
☐ Earth Sciences	☐ Polymers	☐ DOE/NE
☐ Engineering	☐ Physics (Excl Condensed Matter)	☐ DOE/SC
☐ Environmental Sciences	☐ Instrument Development	☐ DOE/Other
☒ Nuc. Physics/chemistry	☒ Neutron Physics	
☐ Astrophysics	☐ Fission	☐ DOD
☐ Few Body Physics	☒ Reactions	☐ NSF
☒ Fund. Physics	☐ Spectroscopy	☐ Industry
☐ Elec. Device Testing	☐ Nuc. Accel. Reactor Eng.	☐ NASA
☐ Dosimetry/Med/Bio	☐ Def. Science/Weapons Physics	☐ NIH
☐ Earth/Space Sciences	☐ Radiography	☐ Foreign:
☐ Materials Properties/Test	☐ Threat Reduction/Homeland Sec.	
☐ Other:	☐ Other:	☐ Other US Gov't:
		☐ Other:

PUBLICATIONS

Publications:

CAARI 2010 Proceedings, AIP Conference Proceedings
April 2011, Volume 1336, Neutron Resonance Spin Determination Using Multi-Segmented Detector DANCE.

Measurement of the 157Gd(n,g) reaction with the DANCE array, Submitted to Phys.Rev.C

Neutron Resonance Spins with a Pattern Recognition Method and Resonance Parameters in 155Gd, in preparation

Abstract: S1522_Sn117-119.pdf

By electronic submission, the Principal Investigator certifies that this information is correct to the best of their knowledge.

Safety and Feasibility Review ***(to be completed by LANSCE Instrument Scientist/Responsible)***

☐ **No further safety review required** ☐ **To be reviewed by Experiment Safety Committee**

☐ **Approved by Experiment Safety Committee,Date:**

Recommended # of days:	**Change PAC Subcommittee and/or Focus Area to:**	**Change Instrument to:**

Comments for PAC to consider:

Instrument scientist signature: **Date:**

Neutron Capture Experiment on ^{117,119}Sn

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1 Introduction

The DANCE array at LANSCE is one of the most advanced facilities in the world for neutron capture experiments. Its high granularity and good timing resolution make it possible to obtain detailed information regarding the multi-step γ-ray cascade from the compound nucleus.

Previously we performed a series of experiments on gadolinium and molybdenum isotopes. The major goal of these experiments was to improve understanding of the neutron capture reaction (including tests of the statistical model in medium mass nuclei), to assign spin and parity of the neutron resonances, and to study Photon Strength Functions (PSFs) and Level Density (LD) below the neutron separation energy.

The experiment on the ^{117,119}Sn isotopes has a similar purpose. Natural abundances of the isotopes are 7.68% and 8.59%, respectively, for ^{117}Sn and ^{119}Sn. The experiment will be performed on highly enriched (above 90%) self supporting metallic targets. The neutron capture reaction Q-value for ^{117}Sn is 9.3 MeV and for ^{119}Sn is 9.1 MeV, which provides an advantage by suppressing background from other tin isotopes, as well as γ rays from capture in most barium isotopes.

2 Motivation

In addition to the nuclear structure issues and the neutron resonance spectroscopy spelled out below, there is practical interest in neutron capture on tin isotopes. There is great interest in the Long-Lived Fission Products (LLFPs: ^{79}Se, ^{93}Zr, ^{99}Tc, ^{107}Pd, ^{126}Sn,

^{129}I, ^{135}Cs) generated in nuclear fission reactors, since the performance of transmutation systems using the neutron capture reaction depends mainly on the cross section of these isotopes [1]. However, there is no experimental data for the neutron capture cross section of ^{126}Sn. The preparation of a high-purity sample is difficult and, moreover, γ-ray radiation from the radioactive sample causes a serious background. A similar difficulty also arises for the study of neutron rich isotopes far from stability. The cross-section is estimated by theoretical model calculations for those isotopes that are difficult to measure and for which no experimental data is available. The PSF, LD and the neutron resonance parameters are crucial ingredients of the Hauser-Feshbach (HF) statistical model calculations. The systematics for these quantities are used to estimate the parameters for the calculations. Extracting those average quantities from the experimentally available isotopes will help to improve the systematics. As discussed below, these studies are also important to understand the basic nuclear structure physics and the reaction mechanism.

2.1 Spin Assignment

The neutron resonance spin is one of the basic quantities that characterize nuclear states. We have developed a new technique [2] for resonance spin determination that is based on the γ–ray multiplicity distribution of the γ–cascade from the compound nuclear resonance. As an example, Fig. 1 shows the distribution of the normalized experimental counts in multiplicity m = 3 and m = 5 for the s-wave resonances in ^{155}Gd. Based on the distribution in multi-dimensional multiplicity space, the spin of the resonances is assigned, as well as the probability of correctness of the assignment.

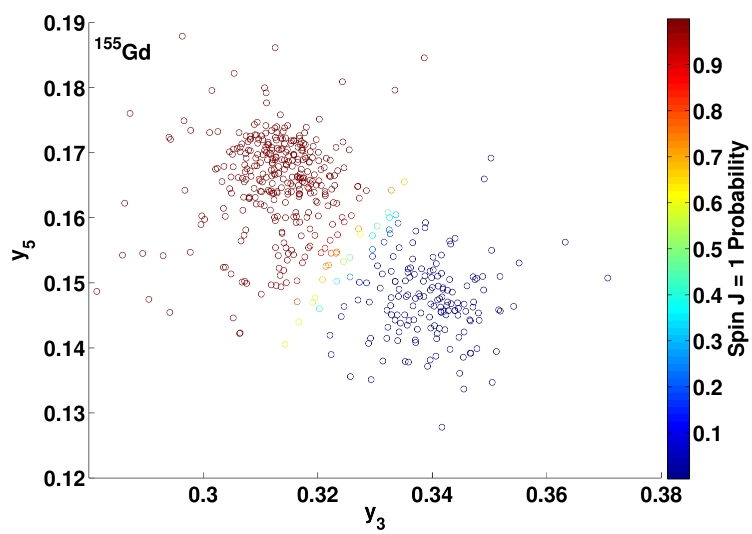

Figure 1: Bayes posterior probability for the 2-dimensional distributions of the s-wave resonances in ^{155}Gd.

The ground state spin for both ^{117}Sn and ^{119}Sn is $1/2^+$; capturing an s-wave neutron excites resonances with spin 0^+ and 1^+, while p-wave neutron capture excites resonances with spin 0^-, 1^- and 2^-. We applied our new technique successfully for s- and p-wave resonances in ^{94,95}Mo. We anticipate applying this new method to the tin isotopes.

2.2 Study of Photon Strength Function

The behavior of the photon strength function at energies below the neutron separation energy is important for a wide variety of applications ranging from stewardship science to nuclear astrophysics to nuclear structure. This energy region can be studied via various methods including the two-step cascade method, the energy spectrum fitting method for neutron capture γ-rays, dipole-strength distributions via photon scattering, and sequential extraction of the γ-spectra from (^{3}He,^{3}He$'$ γ) and (^{3}He,^{4}He$'$ γ) reactions.

For the tin isotopes the pygmy dipole resonances on the low energy tail of the PSF were observed in several different experiments.

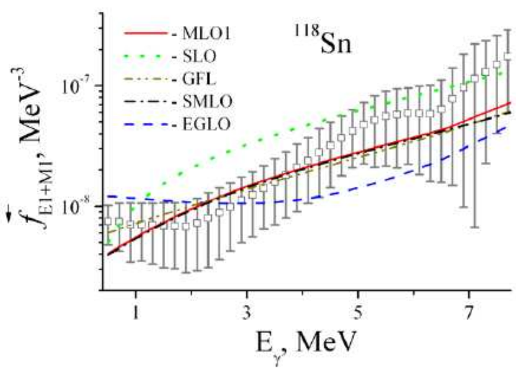

Figure 2: The sum of dipole strengths compared with different phenomenological models. (The Experimental data is taken from [3] and the model calculations are taken from [4])

The two step cascade experiment performed at Řež on ^{118}Sn [3] confirmed that the energy dependence of the dipole PSF, f_{E1+M1}, differs strongly from the predictions of the Brink-Axel (BA) and Kadmenskij-Markushev-Furman (KMF) models. This result is an indication of the enhancement in dipole strength. Several other phenomenological closed-form models with an asymmetric shape were compared with experimental PSFs [4], see Fig. 2.

The Oslo group used the sequential extraction method for the PSF and LD [5]. A significant enhancement is observed for four tin isotopes, $^{116-119}$Sn, in the energy region of E_γ = 4-11 MeV, as shown in Fig. 3. The pygmy centroids of all these isotopes are estimated to be around 8.0(1) MeV. It should be noted that an earlier experiment by Winhold *et al.* [6] using the (γ,n) reactions determined the pygmy centroids for ^{117,119}Sn to be approximately 7.8 MeV. Extra strength has been added in the energy region of $\approx$ 4-11 MeV. The total integrated pygmy strengths are 30(15) MeV mb for all four isotopes. This constitutes 1.7(9)% of the classical Thomas-Reiche-Kuhn (TRK) sum rule, assuming that all of the pygmy strength is E1.

The Sn isotopes have their proton Fermi level located between the $g_{7/2}$ and $g_{9/2}$ orbitals, and their neutron Fermi level between the $h_{11/2}$ and $h_{9/2}$ orbitals. Thus, the simple independent particle model expects a giant M1 resonance to be found at excitation energies near 8.5 MeV due to the proton ($g_{7/2} \leftrightarrow g_{9/2}$) and the neutron ($h_{11/2} \leftrightarrow h_{9/2}$)

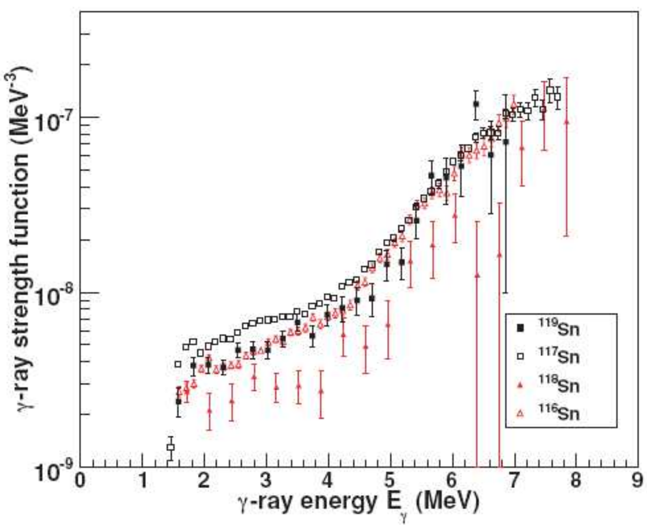

Figure 3: The normalized strength functions for $^{116-119}$Sn isotopes.

spin-flip transitions. The M1 strength in ^{120}Sn was measured at excitations between 7.3 and 9.3 MeV using highly polarized tagged photons [7].

The nature of the Sn pygmy resonances is still unclear – clarification of the E1 or M1 character would be important. In addition, the results obtained by different experiments lead to serious discrepancies, for example for ^{98}Mo.

For this reason, we are proposing to measure neutron capture on ^{117,119}Sn with the DANCE calorimeter. The spectrum-fitting method that we used worked well for the molybdenum isotopes [8]. We simulated the γ-cascade of the compound nuclei based on statistical model assumptions to reproduce the experimental spectra.

The DICEBOX algorithm generates a complete decay of an artificial nucleus. Below some critical energy all characteristics of the decay scheme are taken from existing experimental data. Above this energy the levels and the complete decay scheme are generated using an *a priori* chosen level density $\rho(E, J, \pi)$ and photon strength functions f^{XL} for multipolarities $E1$, $M1$, and $E2$. Partial radiation widths for transitions between all initial and final levels are generated using the postulated $\rho(E, J, \pi)$ and f^{XL} and a random number generated from a normal distribution with zero mean and unit variance. This ensures that the individual transition widths fluctuate according to the Porter-Thomas distribution.

3 Beam Request

Decay γ rays following the neutron capture of ^{117,119}Sn will be detected by the DANCE array, which is located at flight path 14 at the Lujan Neutron Scattering Center at Los Alamos National Laboratory.

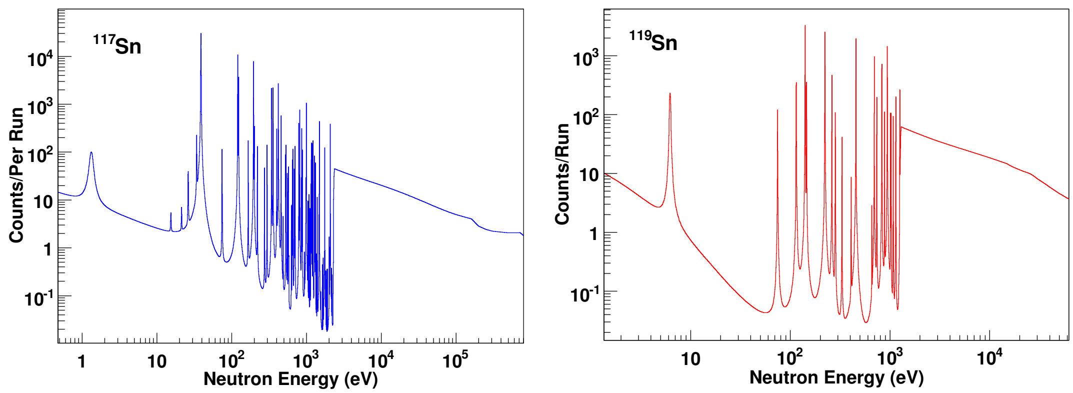

Figure 4: Count Rate estimation based on ENDF Cross section. 2 hours of acquisition is considered 1 run.

We made a count rate estimation based on the ENDF evaluated cross section (see Fig. 4). We expect to obtain 10^4 counts per run at the strongest resonances in ^{117}Sn and 10^3 counts per run for the resonances in ^{119}Sn. The neutron flux is assumed to have a B/E functional form and the normalization coefficient B is estimated fitting previous years measurement.

Based on previous measurements and our count-rate estimates, we expect to obtain sufficient statistics within twelve days: 6 days for each target and 2 days for background and blank runs. We request 14 days of beam time for capture experiments on ^{117,119}Sn.

References

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